Accelerator Physics as a Profession

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Accelerator physics has become a scientific profession in its own right. Besides its complex and intriguing uses of classical and quantum mechanics, electromagnetism, and statistical mechanics, this field has a unique combination of intrinsic characteristics: it is both interdisciplinary and international. It is naturally interdisciplinary in that it encompasses a mixture of science and engineering. Through its connections with sciences and advancing technologies around the world, it is naturally international. This essay presents my view of the status of, and outlook for, accelerator physics as a profession.

In the six decades since Lawrence first accelerated protons to 80 keV in a device that could be held in the palm of a hand, accelerators have grown and proliferated. So have the opportunities and challenges for those who study them, design them, and build and operate them—not to mention those who use them. Table 1, an informal compilation,[1] gives a sense of the variety and scope of major accelerator initiatives worldwide. Each line of the table represents, roughly, a region of the globe.

Table 1

Accelerator Initiatives Worldwide

<u>High Energy Physics</u>

LEP, HERA, CLIC, LHC
Tevatron, SLC, SSC, TLC
TRISTAN, BEPC, JLC
UNK, VLEPP

<u>Nuclear Physics</u>

SIS, Frascati, SIN, Mainz, NIKHEF, ALS
CEBAF, MIT/Bates, RHIC, KAON Factory
BEP/VEPP2M, Moscow Meson Factory, Kharkov/PSR, Troitsk

<u>Dedicated Light Sources</u>

Aladdin, NSLS, ALS, LSV, APS
BESSY, Daresbury (2 GeV), ESRF, Trieste
Photon Factory, Taiwan (1.3 GeV), Korea (2 GeV), Japan (8 GeV)
VEPP-3, Moscow

One can also gain a sense of the variety and scope of present-day accelerators by noting what this table does not even try to reflect: the many smaller research machines as well as FELs, medical accelerators, and industrial synchrotron radiation sources.

A useful distinction can be made between two types of accelerators for physics research. One type includes world-class facilities with unique characteristics and capabilities. At any one time we can have only a few of these, and experimenters may travel great distances to use them. The other type is the regional "workhorse" facility, providing valuable research opportunities to greater numbers of experimenters.

Accelerator capabilities determine which experiments can and cannot be done. The diversity of beam requirements for experimental physics offers unique challenges for designers of

- storage rings and colliders,
- linacs and linear colliders,
- lights sources, and
- FELs.

And just as accelerator capabilities determine possible experimentation, the state of the technological art determines which capabilities are achievable. The challenges for the profession of accelerator physics are therefore not only scientific, but technological. Table 2 is my list of today's technological frontiers for accelerator physics.

Table 2

Technological Frontiers

Superconducting magnets	Beam cooling
Superconducting rf cavities	Rf power sources
Wakefield acceleration	Polarized beam sources
Instrumentation & control	High-intensity beam sources
Lenses	Positron production

One distant part of the superconductivity frontier—high-T_c superconductors—illustrates quite well the linkage between accelerator physics technological frontiers and challenges. It also illustrates how difficult the needed advances can be. To overestimate the ultimate potential of high-T_c superconductors for accelerators is hard, and it is also hard to underestimate their short-term difficulties. The ultimate potential could include higher-field magnets, higher-gradient cavities, and warm operation, but in the nearer term this particular technological frontier confronts us with some very rough terrain in terms of material production, anisotropy, and high rf losses. For the foreseeable future, the materials of choice must remain Nb, NbTi, and Nb_3Sn. As with the other technological frontiers, overcoming the difficulties is not easy. But this does not mean that the effort should not go forward.

There are many frontier areas today where accelerator physics and technology are being challenged. One example is the desire to build linear accelerators with higher gradients, greatly reduced cost per unit energy, and substantially higher energy efficiency. With such devices, the hope is to make feasible colliders capable of attaining super-high ($\sim 10^{35}$) luminosity and very high phase-space density. Attaining super-high luminosity implies challenges in several areas: high-intensity positron beams, beam stability limits, wakefield problems, pinch enhancement, and angstrom-sized beams. Achieving very high phase-space density has implications especially for FELs, and would mean 10^{-6} m normalized emittances and 10^{-3} energy spreads at high currents.

These challenges to accelerator physics are of course only important if we have the prospect of continuing to build and upgrade accelerators. All of my evidence tells me that we do have such prospects; the field of accelerator physics is flourishing. I would like to close by first summarizing what I think are the important things for accelerator builders to remember, and then by offering a suggestion for strengthening the accelerator physics community.

My experience suggests that accelerator builders should be keenly aware of how much expansion they are demanding on the technological frontiers. It is good to push one or two technologies to the limit, but not more. At the same time, it is good for an accelerator initiative to strive for significant improvements over the performance of previous machines. The focus must remain fixed on the physics to be done—that is, on the requirements of the user—and every effort should be made to build a machine that is understandable. By "understandable" I mean a machine of manageable intellectual complexity.

With these general requirements setting the context, I would suggest the following as the specific elements needed for successful accelerator development:

- Bright, enthusiastic people who know what they are doing.
- Close collaboration between accelerator designers and experimentalists.
- Innovative technologies.
- A direction and a plan.
- Adequate funding through the commitment of government.

The last of these is least in our own hands as accelerator physicists and engineers. At the same time, however, it is not at all beyond our reach to influence as members of a scientific profession with a growing record of significant successes and contributions.

The way to ensure that these successes and contributions continue is to strengthen accelerator physics as a scientific profession. By deciding in principle to establish a Division of Beam Physics, the American Physical Society is recognizing the importance of moving in this direction. As with any science, however, a strong professional community must also have formal training programs and independently funded research. It is encouraging to see accelerator physics curricula now being initiated in the universities; one hopes to see more. Independently funded research programs—in the universities and major laboratories, as well as in the smaller laboratories, possibly in cooperation with industry in some cases—will also strengthen the profession. With new Ph.D.-level specialists and with strong programs of basic research in accelerator physics, the field will continue to flourish.

[1]For information on design and status of initiatives, consult L. Teng, "Accelerator Projects Worldwide," and H. Winick, "Synchrotron Radiation," both in *Physics of Particle Accelerators*, AIP Conference Proceedings 184, a 1989 publication of the U.S. Particle Accelerator School.